NOTICES OF MEMOIRS.

Desert Conditions and the Origin of the British Trias.[1]
By J. Lomas, A.R.C.S., F.G.S.

(*Concluded from the November Number, page* 514.)

THE occurrence of salt lakes in deserts is of the greatest interest and importance in the quest we have set before us. They are so characteristic of arid regions that it is essential we should have a clear impression of their peculiarities if we wish to make a true comparison with the rocks of the Trias. They have been described so frequently by travellers that I need only quote one or two examples.

Munzinger,[2] in the "Narrative of a Journey through the Afar Country," describes the great salt basin to the east of the Abyssinian mountains as bordered with walls of gypsum. Further he writes: "The first part of the salt basin is sandy, but after a short distance clay appears on the top, and every now and then we found a rain-ditch with powdered salt in it. After 1½ hours march we found a line of potasse trees, otherwise no tree or bush. The soil by degrees becomes of a greyish tint, and further on resembles a frosted ploughed field; but at the end the bed of salt becomes more thick and hard and presents the appearance of a lake frozen over."

Captain C. G. Rawling,[3] in exploring Central Tibet, visited numerous salt lakes. Of Gore Tso he writes: "A fine lake was seen two miles to the east, but mounds of some white mineral, piled up along the banks, almost certainly indicated that the water was undrinkable. Although this was the 5th of July, the lake was frozen from end to end. . . . On the following morning I made my way to the shores of the lake and found . . . all around rose a solid ridge of salt deposit, three to four feet high and from thirty to forty feet wide. No vegetation grew within 500 yards of the shores, while to the north a barren plain stretched away for many miles. The lake is about 20 square miles in area."

Sven Hedin, writing of the Takla Makan desert, states that the dunes are arranged in a sort of network pattern with hollows—or bayirs—inside the meshes. Clay rises as oblong terraces or steps four to five feet high along the slopes, giving the appearance of beach lines. The bottom of the bayir is covered with a granular hard incrustation of salt, at a distance resembling rime. Upon digging eight or nine inches a thick deposit of pure salt is reached, evidently filling the bed of a desiccated salt lake, the margins and side terraces of which are coated with perfectly horizontal layers of yellowish-red clay eight to nine inches thick and hard as stone. In some bayirs a part remains moist, and is edged all round with a narrow belt of salt. A bed of gypsum was observed in some cases, and one contained the skeleton of a water bird and a dead day-fly.

[1] Proc. Liverpool Geol. Soc., vol. x, pt. 3, 1907, pp. 172–180; slightly abridged.
[2] Geog. Journal, 1869, p. 200.
[3] "The Great Plateau," p. 61.

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The above excerpts give one a good idea of what the desert salt lakes are like, and one or two facts common to all are worth noting. First, we have the clay bottom sometimes augmented in thickness by layers of sand which have drifted into the pool; then we note the constant association of salt and gypsum in the deposits. It is well known that concentrated brine precipitates the sulphate of lime out of solution. Further, we have no mention of carbonate of lime as one of the constituents left after evaporation, or, at least, if present it is not in sufficient quantity to call for special notice. Yet in the waters flowing from the hills towards the lakes this substance, as the bicarbonate of lime, must have been present, and probably exceeding the others in amount. The explanation is simple. The bicarbonate is chemically not a stable compound, and readily parts with the excess of carbonic acid. Hence, in passing over or through the soils the carbonate of lime will be precipitated and form the nodules and limestones described above, while the more chemically stable compounds will reach the lakes undiminished in quantity.

So it happens, as we should expect, that carbonate of lime segregates on the land, while salt and gypsum are the chief substances left as residues in the desiccated pools. Dolomite in perfect rhombohedral crystals is occasionally found in association with the products of desert pools.

Drifting sands blowing over the plains may fill up the hollows and leave no sign on the surface of the pools which formerly existed there. The lake deposits would still be there buried under the sand, and if a section could be made through them we should find beds composed mainly of sand with thin bands of clay following the limits of the lake and irregularly disposed at various horizons. On the margins the clay would show desiccation cracks and ripple-marks, the footprints of animals, and the remains of such forms of life as find a suitable habitat under such conditions.

Mr. T. H. Holland,[1] referring to the deposits in the Rajputana Desert, states that silt beds occur, filling in hollows in the Archæan surface. They have a general plano-convex lens shape, and are charged with salt, beds of gypsum, and concretionary nodules of carbonate of lime.

In our Triassic rocks we get the exact counterpart of these filled-in desert lakes. Bands of clay occur in all the divisions, but they are more common in the higher beds. When the full extent of the clay bands can be determined, they are always half lenses in shape, with the convexity downwards. It is on the lower surfaces of the sandstones, immediately resting on the clay, that we find casts of footprints, raindrops, ripple-marks, and desiccation cracks, and the clays often either contain pseudomorphs of rock-salt or deposits of this mineral and gypsum overlie the clay. The salt beds of Cheshire have these associations, and are now generally regarded as resulting from dried-up pools or lakes. Even when beds of pure salt are absent it is found that water from the Keuper Marls is almost invariably strongly impregnated with salt. It may be that where beds of pure salt are

[1] Brit. Assoc. Report, 1906, p. 575.

found they have been covered by drifting sand after complete desiccation of the pool, and when the salt is intimately mixed with the rock the wind-borne material was deposited in the pool while some water remained.

Dr. Cullis has recently described the occurrence of dolomite crystals in the Keuper Marls of the West of England. So far they have not been found in our locality, although carefully looked for.[1] We cannot say at present how these crystals have been formed, but their presence in recent deserts and in the Triassic rocks is of interest.

When dealing with the subterranean water supply of the desert it was pointed out that the impermeable bands which confine the water below show very striking differences of level. If these bands of clay can be regarded as the silt covering the floors of filled-up pools our difficulties are most satisfactorily met. (See p. 512.)

Thus far we have dealt with the part water plays in the economy of the desert. The waste of sand stretching as far as the eye can reach gives little sign of the activities below the surface, and it is chiefly there that water has its work to do.

Surface Deposits.—We turn now to discuss the surface deposits themselves. It must not be supposed that even in the so-called sandy deserts the surface is uniformly covered with loose fragmentary materials. In the Algerian Sahara probably less than one-third is covered with sand. Solid rock forms the floor of vast barren plains, or stands as islands or cliffs washed by great seas of sand. However, it is mainly with the sand (and in this term we may for convenience include pebbles) that we have to deal.

Origin of the Sand.—The sands of the deserts were naturally at first attributed to marine action, and the presence of salt deposits no doubt gave verisimilitude to the idea that they represented dried-up sea-bottoms. Zittel, Tissandier, and others have shown that the fragmental material is of subaerial origin, and has been derived by the action of the ordinary disintegrating forces at work on the land.

In a climate such as ours it is hard to appreciate the importance of one of the most active disintegrating agents in the desert. One needs to stand under the tropical sun and in the presence of the riven rocks to fully appreciate what sun-flaking means. Unprotected by vegetation or covering soils the bare rocks become intensely heated during the day; when the sun's heat is withdrawn they rapidly chill by radiation, and thus by alternate expansion and contraction even the most compact and resistant rocks yield. A characteristic form assumed by sun-flaked rocks is the spheroid, and one is reminded of the spheroidal weathering often seen in basalt. In a cuboidal mass of granite the solid angles are the first to split, and then the edges go, and so flake after flake is removed until the block resembles a well-worn boulder. The flakes are usually from half an inch to a little more than an inch in thickness, but their horizontal extent may be many yards. After flaking, the smooth curved surfaces give one the impression of *roches moutonnées* when viewed at a distance, and

[1] It might be noted that dolomite occurs in plenty in the sands dredged from the Mersey bar.

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individual spheroids resting on these surfaces resemble perched blocks. At the foot of a cliff screes of angular flakes tend to accumulate. These still further break up under similar influences and finally form sand. They may accumulate until the rock is buried under its own fragments, or in the rainy season the loose material may be carried away to form sandy deltas, and the surface of the solid rock may be kept open for further flaking. Sands resulting from the disintegration of granite and other rocks in the desert are in striking contrast to those formed in our own country in so much as chemical action takes no part in the breaking down of the rock. The fragments are chemically unaltered, and the flaked surfaces consist of perfectly fresh minerals. Of course, in the neighbourhood of mountains sufficiently high and conveniently situated to intercept moisture-laden winds, both chemical and mechanical disintegration may take place and streams may flow into the lowlands, mingling water-borne material with that of desert origin.

It is difficult to apply the tests of sun-flaking and the characteristics of desert sand to our Triassic deposits, as so few places exist where they are seen to lie on the rocks which gave them their origin. However, in the neighbourhood of Leicester, in Charnwood Forest, on Mount Sorrel at Croft, and at other places where the Keuper rests on the igneous rocks we get the very best conditions for making the comparison. Professor W. W. Watts has shown that in this district the Keuper fills up hollows in the older rocks, and denudation is now uncovering the old pre-Triassic landscape. The older rocks, particularly at Mount Sorrel, present curved flaked surfaces exactly like those described from the desert. Loose blocks are flaked into spheroids and lie tumbled in the Keuper Marls, which must have been accumulating at the time the blocks fell from the cliffs above. Screes of angular flakes rest against the ancient slopes, and the sand is composed almost exclusively of material from the adjacent rocks. Moreover, the surfaces of the rock, the scree material, and the sand are all chemically fresh.

The absence of decomposition products is well seen, too, in the Keuper sandstones of our own neighbourhood in places where infiltration has not taken place. When a clay band occurs in a rock face, the felspars in the top portion are usually kaolinised by the percolation of surface waters, but below the impervious layer they are remarkably fresh. This conclusively demonstrates that when they were laid down they were not subject to chemical changes.

Work of the Wind.—During the dry season the wind does its own work in carrying, sifting, rounding, and etching.

(1) *Carrying.*—In open ground driven sand tends to accumulate in ridge-shaped masses, the long crests lying transversely to the wind. When a dune of this kind has been originated the wind blows grains up the exposed slope and over the summit, where they drop on the leeside. The slope to windward is gentle, and on the leeside steeper and slightly concave. The concavity is due to a backward eddy which sets in as the wind passes over the crest, and can easily be demonstrated in our local sand-hills by putting a piece of paper or any light object against the leeward slope when a stiff wind is blowing. The paper will be seen to move up the slope against the wind.

In our neighbourhood the dunes seldom exceed 50 feet in height, but in the desert they have been measured up to 350 feet. A favourite simile with travellers is to compare dunes with the waves of the sea, with crest and trough following each other parallel in sequence or arranged in a network pattern.

One fundamental difference must be kept in mind; in the sea the wave motion progresses while the material is stationary. In the desert the sand travels with the wave movement. The Arabs say that the dunes 'walk.' It follows, then, that if the material goes forward the country to windward will be left bare unless fresh material is forthcoming from that quarter. Deposits accumulated by wind action show very characteristic false bedding. The nature of this depends on the steepness of the slope over which the sand tumbles and the varying directions of the wind. When the slope to leeward is very steep the weight of the sand at the top may cause the sand to slide down into the hollow, thus puckering and folding the layers beneath.

The distance to which sand may be carried by wind is very great. Dust-storms are sometimes met with in the Mid-Atlantic which can only have come from the western Sahara. At Las Palmas a ridge of sand dunes exists on the low isthmus connecting the Port with Isleta. The rocks of the island could not yield such a deposit, and captains of ships attribute the sand to winds blowing from the African continent. The finest sand dust may be carried in the air for hundreds of miles, and when the winds are constant the result will be the building up of thick masses of stratified material. Such is the origin attributed to the Loess of China, which attains more than a thousand feet in thickness, and Richthofen supposes it to have come from the desert areas of Asia. Professor N. S. Shaler[1] assigns a similar origin to the accumulation of fine-grained detritus in the Western Mississippi Valley, and he states that it has been derived from the Cordilleras.

(2) *Sifting.*—The sifting action of wind may be observed in a dusty road or in our local sand-hills. In deserts, however, where the winds blow more consistently from one quarter, the action is more perfect.

In a series of samples taken in the Sahara from the same locality in vertical sequence by the late Dr. Isaac Roberts the grains differ in size at each horizon, but for the same depth the sifting is so perfect that it looks as if each sample had been put through a sieve. Many other observers have commented on the sifting action of wind, and it is only reasonable to suppose that the size of a grain carried along will vary with the velocity of the current which moves it. Sven Hedin graphically describes a sand-storm he encountered in Central Asia. Near the ground the wind velocity was 40½ miles an hour. Six feet from the ground it measured 58½ miles an hour. Branches, tufts of grass, and grains as big as peas whirled in the air and struck his face with stinging force. A strong wind such as that described will move large and small particles alike, but as it loses velocity the particles will drop to the ground as the carrying power of the wind diminishes. Thus the sands raised by one storm will be graded horizontally,

[1] U.S. Geol. Survey, 12th Report.

gradually getting smaller to leeward. The same sands may be worked up again and again by currents of differing velocities, and hence we should not expect to find the layers of even-sized grains to persist over very great distances. Again, the grains are not all composed of materials having the same relative density. Although quartz predominates, we find mica, felspar, magnetite, zircon, and other minerals, and each will be affected according to its linear dimensions and specific gravity.

If we consider two particles of different sizes and having the same terminal velocities when falling under gravity we find the resistance varies as the square of the linear dimensions, and the weight jointly as the cube of the linear dimensions and the specific gravity. This is only a very simple and incomplete way of stating a very complicated problem, but it is possible to find in terms of their relative densities and dimensions the sizes of the different kinds of grains which will come to rest together.

We have already seen that where temporary streams flow down from high grounds fans of gravel are produced where they debouch into the plain, and along the beds of watercourses there exist layers of gravel, composed of water-worn stones. The distance these stones have travelled from their place of origin depends on the character and volume of the stream which brought them. It may be reckoned in miles or scores of miles. We pictured above (p. 511) the character of the deposits formed by the successive excavation and filling up of river valleys, and gave instances where sands with bands of pebbles intercalated at various horizons had resulted from this action. What is the effect of winds blowing over a deposit of this nature? The sands are carried by the air currents and form dunes, but the larger stones are too heavy to be moved and form a loose pavement on the desert floor.

According to Mr. H. T. Ferrar, of the Geological Survey of Egypt, these pebble layers may be so thin that the tread of a camel may break through and send up puffs of the sand from below at every step. At other times they are more than 100 feet thick. These may result either from excessive rainfall and strong currents of water or from the successive accumulation of materials brought down by streams through many wet seasons, and the removal of the finer material during many dry seasons. In any case, we have in deserts great spreads of gravel brought down by rivers and reassorted by wind action.

(3) *Rounding and Etching.*—Sands caught up by the wind and hurled against each other have a greater velocity and hence a greater impact than those carried along by moving water. In river and sea sands rounding does take place, but it does not approach the perfection seen in sands which have been subject to prolonged movement in air. The constant battering of grains against each other not only results in rounding, but in the production of excessively fine splinters of sand. It is this sand dust which is carried to great distances by winds and tends to accumulate on the lee sides of desert regions. Particles too heavy to be lifted bodily in the air are rolled along the ground. If it happens that the length of

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a grain is great as compared with the width the rolling may be confined to one axis of revolution and a cylindrical form results. Cylindrical grains of this nature are not uncommon in desert sands, and they are found in the dunes round our coasts. The sands rolling up a slope often form the most exquisite ripples, giving the appearance of tiny dunes riding on the larger ones. Perfect spheres do not, as a rule, result from the attrition of very small grains, and we seldom find 'Millet seed' sands with a diameter of less than ·5 mm. Not only does abrasion take place by the striking of one grain against another, but the battering of grains against the solid rocks or against loose stones lying on the surface of the desert results in some characteristic effects. The effects produced on the rocks will vary not only with their hardness and texture, but also with the angle at which the impact takes place.

A glass tumbler dropped by a tourist in the desert was found after a time to be frosted and opaque on those parts exposed above the sand. It exactly resembled the sand-blast labels on our reagent bottles and the designs frosted on glass intended for ornamental purposes.

Blocks of obsidian found in the deserts of Iceland likewise become frosted on their exposed surfaces. Granite on the other hand takes a beautiful polish. If the rocks contain minerals of varying hardness the softer constituents tend to form hollows, while the harder materials stand out and are sometimes completely disengaged from the mass. In this way the fossils in the nummulitic limestone of which the Great Pyramid is built stand out from the surface, and large numbers of loose nummulites can be found in the sands surrounding the base of the pyramid. So perfectly and so intimately does the sand pick out the parts of superior hardness, or of looser texture, that pieces of silicified wood can be found in the neighbourhood of Cairo with the vascular fibres standing out from the less compact parenchymatous tissue.

Mr. W. D. Brown[1] recently described before the Liverpool Geological Society some most interesting experiments which he performed with artificial sand blast on various rocks. He showed that a blast with a pressure of 45 pounds to the square inch, acting perpendicularly on sandstone, drilled a cylindrical hole and removed 435 grains in 5 minutes, whereas the same blast acting on the same piece of rock at an angle of 45 degrees produced an even plane surface and only removed 400 grains in 10 minutes. A piece of granite with an oblique blast lost 200 grains in 5 minutes, while limestone lost 323 grains in the same time and under similar conditions. All the stones subjected to the experiments possessed rounded surfaces before being acted upon, but the sandstone and limestone were reduced to plane surfaces while the granite showed differential action, the quartz standing out from the softer constituents.

The production of a plane surface by oblique sandblasting may be compared with the action of a file drawn over a curved surface. Being rigid, the file moves in a straight line, it does not accommodate

[1] Proc. Liverpool Geol. Soc., vol. x, p. 130.

itself to the outlines of the substance, but produces a sharp cut edge where it leaves the object. Similarly, sand moving with great velocity keeps its initial path, while similar particles moved slowly by a current of water over a curved surface would roll over the leeward slopes and abrade during their descent. It must not be concluded that a plane surface can only be produced by the action of wind-driven sand. In Switzerland I have seen plane surfaces and sharp cut edges, produced in the beds of torrents carrying sand in suspension, quite indistinguishable from those produced by wind action. The plane surface then is largely a result of high velocity, and while this is of rare occurrence in currents of water it is common in currents of air.

When driven sand strikes a stone in the open desert it is deflected upwards and round the sides so that plane surfaces are formed on three planes. This is the typical form to which the name 'dreikanter' has been applied, and the finding of these in any deposit is regarded as one of the surest indications of wind action.

Sand blowing over a flat surface of rock tends to widen joints and open them out into a funnel shape, with the wide end facing the direction of the wind. The sides of the opened joints, too, are almost invariably undercut.

It has been shown by Professor Watts, Mr. Walcot Gibson, and others that the surface of the country had been carved by denuding forces into valleys and hills before the Trias was deposited. The newer rocks, by filling in the low grounds, smoothed down the landscapes, and in some places hills were completely covered. In no part of Britain do Triassic rocks attain a greater altitude than 800 to 900 feet above sea-level at the present day, and we have no proof that they ever extend much above this level. They are essentially deposits of the lowlands. Their distribution has been admirably summarised by Professor Bonney,[1] and I can add nothing to his lucid description of their occurrence. He shows that there exist two foci of coarse fragmental rocks, one in the western and northern Midlands and the other in Devonshire. No one now doubts that Professor Bonney is right in claiming these coarse deposits as of fluviatile origin. At the places mentioned, rivers reached the plains (whence they came does not matter at present) bringing down pebbles, well worn in transit, and no doubt a large amount of finer material as well.

Taken as a whole the deposits get finer as we go away from the foci, and on the extreme borders of the areas covered by Trias they consist of exceedingly minute fragments. At a subsequent stage in the history of the Trias, pebbles occur again, indicating a return to the conditions under which the lower beds containing pebbles were formed.

Assuming that desert conditions prevailed during Triassic time—interrupted, perhaps, by pluvial periods, when rapid streams brought down the pebbly constituents—let us see how far they show evidence of the action of wind. Except in the finer deposits such as the Keuper Marl true bedding is almost entirely absent. Current bedding there is in plenty, and frequently very steep—too steep, indeed, for the angle of rest of sand laid down in water. In extreme cases of steep false

[1] "*On the Origin of the Trias*": *Proc. Yorks. Geol. Soc., vol. xvi (1906)*, p. 1.

bedding the sands are often contorted at the bottom of the basin as though the weight of the sands above had caused a slide such as we have described as taking place in sand-hills.

It is difficult to describe the structure of the sandstones; there are no geological terms exactly suitable. They have the appearance of a tumbled series of eroded lenticles. Anyone who has had the misfortune to map them knows how the beds thicken and thin out promiscuously, and how difficult it is to find a datum-line which will be of service in correlation. Even our late member and founder, Mr. Morton, whose knowledge of our local rocks was so intimate and extensive, would never give an opinion as to the horizon of a piece of Trias sandstone from a hand specimen. The only approaches to satisfactory datum-lines we possess are the two horizons where pebbles occur, and even these are only of service locally, as they are limited in extent. In sections cut through dunes in the desert between Ismailia and Kasassin I have seen beds very much resembling those I have attempted to describe above.

The marginal beds of the Trias area are almost without exception the Keuper Marls. They are found also covering the sandstones in the middle of the area, and sometimes they are intercalated with beds of sandstone. They are not strictly marls, but are composed almost exclusively of exceedingly fine and angular quartz dust. It has been suggested that they have been laid down in a lake, or a series of lakes, and the even bedding which they show is given as a proof. But bedding even more perfect may be seen in volcanic dust deposited on the land, and, further, Mr. T. O. Bosworth has shown that when the Keuper Marl rests against a sloping cliff the bedding slopes with the surface of the ground. This is quite unlike the conditions we should expect to find if it had been of subaqueous origin. Lakes of the desert type are found as local phenomena in the Keuper Marls, and have been referred to in a previous part of this paper. The marls may represent the smallest tailings of wind-carried material.

The sifting action of wind is everywhere evident in the Trias. Besides the horizontal grading already mentioned which characterizes the deposits broadly as a whole, we find that locally the same sifting influences have been at work. Sands of exactly the same dimensions occur as lenticular patches, a few feet or several yards in length. These are associated with other lenticles of larger or smaller grain, but in the same patch there is no admixture of large and small sizes. In our neighbourhood they are best seen at the top of the Bunter, immediately underlying the Keuper basement bed. The perfection of sifting into sizes shown at Bidston and at Scarth Hill is marvellous, but in other places and at other horizons the some features may be observed.

The concentration of pebbles from river deposits is also paralleled in the Trias. The pebble beds of the Midlands, although originally of fluviatile origin, do not exhibit the characteristics of river action. The individual pebbles show no orientation in the arrangement of their longer axes, but are wedged together in a tumbled mass as if they had dropped into their present situations by the removal of material about them. The insecurity of their positions is evidenced

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by the pitting which has resulted from their successive readjustments. The interspaces between the pebbles are almost free from sand, but lenticular seams of sand occur, which may have been protected from removal by wind, when the pebbles formed a continuous covering. There are places in our own district where it does not appear that concentration took place, and the sand with pebbles marking the situations of temporary streams still persist as originally laid down.

The occurrence of millet-seed sands in the Trias is too well known to need further comment, and they have always been attributed to wind action. Professor Watts,[1] too, has shown that the surfaces of the Mount Sorrel granite, when freshly uncovered from the mantle of Trias, show very characteristic wind etching, and at Croft the underlying igneous rocks have their joints widened and their vertical faces undercut in a way that could only be produced by wind. 'Dreikanter' occur sparingly in the pebble deposits. They are not common even in recent deserts, for only the surface pebbles can come under the influence of the wind.

This paper is not intended as a description of the Triassic rocks themselves, but to institute a comparison between the features and activities of existing deserts and the Trias rocks of our own country. The question has been discussed entirely from the physical standpoint. The palæontological aspect still remains to be considered. The animal and plant associations, and their adaptations to the peculiar circumstances under which they live in the desert, should find their counterparts in the Trias, if arid conditions existed during their formation.

REVIEWS.

I.—Rock Minerals. By Professor Joseph P. Iddings. (New York: Wiley & Sons, 1906.)

DURING the last ten years so many advances have been made in the microscopic study of minerals, and so many new species have been recognised among the minerals of rocks, that the need for a new textbook of the subject in the English language has been much felt. Professor Iddings' book is in some ways not unlike the well-known Rosenbusch Iddings', which has served the needs of several generations of students. It is really, however, a new work, as a very excellent introductory or general part has been provided in which the chemical, physical, and optical properties of minerals are described, while the second or descriptive part is entirely remodelled and brought up to date. It is not difficult to trace the influence of certain standard authors in the treatment of some parts of the subject; more especially that of Professor Groth in the chapters on optical properties, and of Professor Rosenbusch in the special descriptions of the minerals. But the book has a marked individuality owing to the bright and interesting manner in which the author has handled his materials. It is brief,

[1] Geological Journal, 1903.